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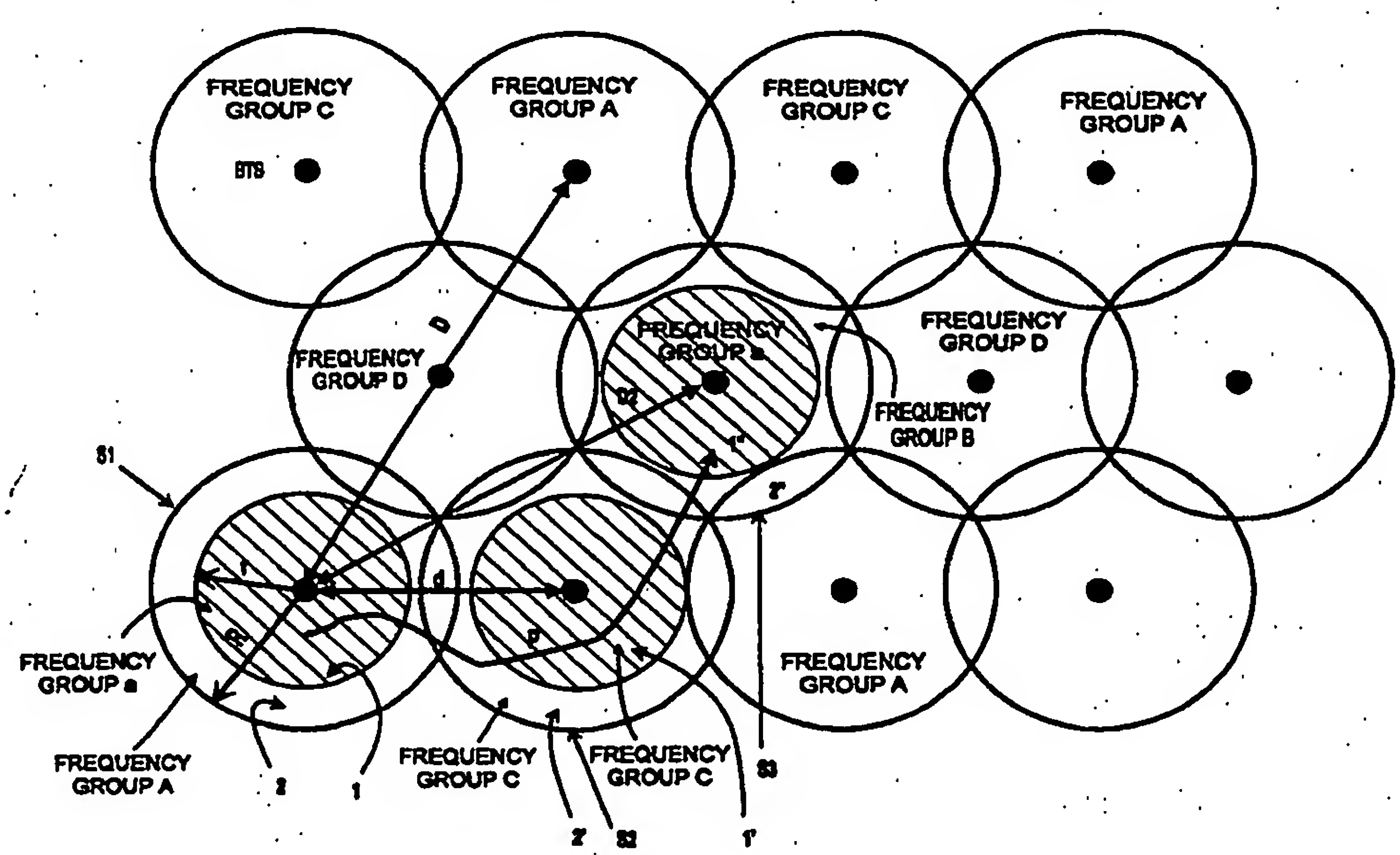

(57) Abstract

In the cellular mobile telephone network of the invention, at least one carrier of the frequency group of a cell is transmitted at a lower power than the highest allowed transmission power of the base station, the radio coverage of the lower-power carrier thus establishing a sub-cell (1) within the mother cell S1. When a mobile station is located within the sub-cell (1), it is allocated a traffic channel the frequency of which is the frequency of the lower carrier, and when a mobile station is located outside (2) the sub-cell but within the moter cell, it is allocated a traffic channel the frequency of which is the frequency of a high-power carrier. As the mobile station moves into a sub-cell or correspondingly out of it, a handover is performed in which the mobile station is allocated a traffic channel which uses a lower-power or, correspondingly, a higher-power carrier. The frequency reuse factor can thus be reduced as regards the lower-power carriers.

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Increasing capacity in a cellular mobile telephone network

The present invention relates to a cellular mobile telephone network, in which each cell is allocated specific frequencies differing from those of neighbouring cells, in such a manner that the same frequencies recur in other cells according to a frequency reuse factor.

One basic idea of a cellular mobile telephone system is to use the limited frequency band of the system in such a manner that required capacity can be provided despite the limited number of frequencies. This is carried out by establishing cells. A cell does not have the use of all the frequencies of the system, but a specific group of frequencies. Neighbouring cells do not have the use of the frequencies of the frequency group of this cell, but these frequencies are only used in a cell which is located sufficiently far from the cell concerned. Signal strengths have thus decreased sufficiently between the cells using the same frequencies, co-channel interference being also sufficiently low and not causing disturbance on the radio channel. The procedure where frequencies are distributed according to the above-mentioned principle is referred to as frequency reuse.

The above-described procedure is essential in cellular design, which aims at selecting the cell size and the number of system parameters, such as frequency allocation and cellular capacity, in such a manner that such a continuous coverage is achieved economically that supports the required traffic intensity. Factors to be taken into account in cellular design are thus traffic intensity in different areas, the greatest transmission power of mobile stations, and interference.

The term "frequency reuse factor" related to the use of frequencies depends on the cellular design of the operator, and interference restrictions also set a limit

to the frequency reuse factor. The frequency reuse factor has a significant effect on the efficiency of the spectrum. The smaller the frequency reuse factor, the more efficiently the frequency spectrum is used. The frequency reuse factor is determined on the basis of relative interference levels, C/I levels, in which C is the level of a received carrier and I is the interference level. The factor C is affected by the used handover strategy, the power control of mobile stations, discontinuous transmission DTX, and frequency hopping.

In a completed network, a cell is allocated a dedicated frequency group, i.e. a particular number of carriers of a particular frequency, and the frequency reuse factor indicates how far from this cell the same frequencies are reused. Even though a cell is allocated a specific number of carriers, this does not mean that all the carriers are used. Accordingly, if the capacity of the cell is to be increased, it can be normally increased by starting to use more carriers from the frequency group of the cell.

The allocated frequency spectrum sets an upper limit to the highest achievable network capacity. To illustrate this, reference is made to Figure 1, which is a schematic representation of a geographical area covered by the cells of a cellular network. For the sake of clarity, it is assumed that the cells are of the same size and that they can be represented by circles which have the same radius; base stations BTS indicated by black circles are located in the center of a cell; and the distance from a base station to another is d. It is assumed that the frequency reuse factor is 4, from which follows the known fact that four frequency groups are needed: frequency group A, frequency group B, frequency group C, and frequency group D. The same frequency group can thus recur in such a manner that a cell of another frequency group is

located between cells of the same frequency group, for instance in the manner shown in the figure. The carrier frequency is thus reused at a distance D. Assuming that two carriers are provided for a cell, i.e. that each frequency group includes two carriers, the total number of the carriers being thus 8, and assuming that a carrier requires a 200 kHz band as in the GSM system, the frequency band required by the exemplifying system of the figure would be 1.6 MHz. This shows the problem associated with known networks that the network frequency band sets an upper limit to network capacity. In order to increase the capacity, the number of the carriers should be increased, and this can only be carried out by enlarging the frequency band.

The object of the present invention is a cellular network in which, contrary to known networks, the capacity can be increased without enlarging the frequency band. This is achieved with the cellular network defined in claim 1.

According to the invention, at least one carrier of the frequency group of a cell is transmitted at a lower power than the highest allowed transmission power of the base station, the radio coverage of the lower-power carrier thus establishing a sub-cell within the mother cell. When a mobile station is located within the sub-cell, it is allocated a traffic channel the frequency of which is the frequency of the lower carrier, and when a mobile station is located outside the sub-cell but within the mother cell, it is allocated a traffic channel the frequency of which is the frequency of a high-power carrier. As the mobile station moves into a sub-cell or correspondingly out of it, a handover is performed in which the mobile station is allocated a traffic channel which uses a lower-power or, correspondingly, a higher-power carrier.

The invention will be described by means of an embodiment with reference to the accompanying schematic drawings, in which

Figure 1 shows the cells of a cellular network and their frequency groups when the frequency reuse factor is 4,

Figure 2 shows the cells of the cellular network of the invention.

The cellular network of Figure 2 principally corresponds to Figure 1, and the same references are used where applicable. Let us examine cell S1. The radius of the cell is R, and it is the carrier range of the frequency group A, beyond which signal strength deteriorates fast below an acceptable value and beyond which the carrier of the base station of a neighbouring cell is more audible. In practice, the signal strength of the carrier is great as far as at the cell border and also at some distance within the area of a neighbouring cell, and this is why neighbouring cells are not allocated the same frequencies.

As is known, one of the carriers of the frequency group A is one on which the base station broadcasts information intended for all mobile stations moving within the area of the cell. In the GSM mobile telephone system, such a carrier is the BCCH carrier (Broadcast Control Channel), and frequency correction, synchronization and general base station information is broadcast on channels using this carrier. In addition, this carrier is used for transmitting pagings and paging acknowledgements by using an appropriate CCCH channel (Common Control Channel). Due to the nature of the channels using this carrier, the BCCH carrier is continuously transmitted at the highest allowable capacity. Instead, the power of the other carriers of the frequency group is adjusted in the known manner according to the requirements of the traffic

channel using the carrier.

At the base station of the cell S1, the power of the transmitter of at least one carrier is adjusted in such a manner that the coverage of the carrier is about half of the cell. The power of the carrier is thus a part power of the highest allowable power. However, the carrier must not be the BCCH carrier, which is continuously broadcast at the highest allowable capacity according to the specifications. The range r of the lower-power carrier is thus about 71% of the radius R of the cell, i.e. r = R/sqrt(2). The cell with the radius r constitutes a sub-cell 1, and the actual cell with the radius R will be referred to as the mother cell below. The area 1 of the sub-cell is indicated by oblique strokes in the figure, and the area 2 of the mother cell, which the sub-cell does not cover, is indicated by a white area. In this example, the area 2 is an annular area. According to the invention, a frequency group a comprising at least one carrier frequency is employed within the area of the sub-cell 1, the transmission power of the carrier/carriers being lowered. The other frequency group A of the cell consists of carriers the transmission power maximum of which is the highest allowable one.

Let us examine a case where a mobile station moves along a path indicated by line P. The mobile station, which is located within the area of the sub-cell 1 of the cell S1, is allocated a traffic channel from the frequency group a, the frequency of which traffic channel is the frequency of the lower-power carrier. The power of the carrier of the traffic channel is adjusted according to normal power regulation, in such a manner, however, that the maximum power is no more than the above-mentioned part power. When the mobile station moves within the mother cell out of the sub-cell 1 into the area 2 of the mother cell, an intracellular handover is performed, and

the traffic is transferred to a traffic channel the carrier of which is a carrier of the frequency group A and the power of which may thus reach the highest power allowable to a carrier of the cell.

When the mobile station moves further out of the cell S1 into the area 2' of a neighbouring cell S2, an intercellular handover in performed in a manner known as such. The traffic is transferred to a channel of the cell S2, the power maximum of the carrier of the frequency group C of which covers the entire area of the cell S2. When the mobile station moves further from the area 2' of the mother cell S2 into a sub-cell 1', an intracellular handover is performed again, and the traffic is transferred to a channel the carrier of which belongs to a frequency group c, the maximum power thus being a part power of the highest allowable transmission power. When the mobile station moves out of the sub-cell 1' into the area 2', the carrier frequency is selected again from the frequency group C.

When the mobile station moves into a cell S3 to an area 2'', an intercellular handover is performed again according to the criteria characteristic of the network, and the traffic of the mobile station is transferred to a carrier of the frequency group B. The power of the carriers of this frequency group may be the highest maximum power allowable to the cell. When the mobile station moves further to a sub-cell 1'', an intracellular handover is performed, and the radio channel is transferred to a carrier of the frequency group a. The transmission power of the carriers of the group a is lowered.

As can be noticed, the frequency groups of the sub-cells of the cells S1 and S3 are the same, i.e. the frequency group a. In other words, the frequencies are reused at a distance D2 from one another. Since r =

R/sqrt(2), the distance D2 must be longer than or equal to D/sqrt(2). It is therefore possible to use a frequency reuse factor 3. What is described above is due to the fact that a low-power transmission attenuates to a tolerable level faster than a high-power transmission. On the other hand, the payload signal is weaker. For instance, when the mobile station is located in the sub-cell 1 near the border of the mother cell and when a carrier k of the frequency group a is used for communication, the carrier k of the frequency group a, arriving from the sub-cell 1'' of the cell S3, has attenuated sufficiently when arriving at the mobile station, the C/I ratio being thus sufficiently great. Without the operation of the invention, the frequencies would be reused only at a distance D from one another.

If the frequency group of each cell comprises two carriers, one of them could be used as a lower-power carrier to establish a sub-cell, and the other carrier could be used as a BCCH carrier, which must cover the area of the entire cell, as is known. If a frequency group comprises several carriers, desired carriers can be selected to be lower-power carriers, which can be used for communication within the sub-cell and which can be reused at a shorter distance than the frequency group of maximum power carriers.

With the use of lower-power carriers, the frequency reuse factor can be reduced as regards these carriers in accordance with the above. For instance, the same carriers can be used in the sub-cells of the cells S1 and S2, while the inference caused by them does not grow too high due to the lowered maximum power. As regards these carriers, the frequency reuse factor is 3 in the example of Figure 2, since the same carriers are reused at a distance D2, which is approximately the same as three times the radius R of the cell. If a cell is provided with

two carriers and one of them is a lower-power carrier, the required bandwidth is 1.4 MHz. The bandwidth required of a prior art network using two carriers per cell is 1.6 MHz, the improvement being thus significant.

The presented solution is suitable for use in connection with any known cellular network. Since the number of intracellular handovers increases, it must be taken into account in an appropriate manner in network planning and in handover algorithms. It may be necessary to develop a new algorithm and new parameters for network configuration.

The above description and the figures relating thereto are merely intended to illustrate the present invention. Different variations and modifications of the invention will be apparent to one skilled in the art, without deviating from the scope and spirit of the invention disclosed in the appended claims. Accordingly, several frequency groups having different transmission power can be established per each cell, each carrier constituting a separate frequency group in an extreme case. Numerous sub-cells are thus established, the disadvantage of which are numerous intracellular handovers.

Claims

1. A cellular mobile telephone network, in which the base station of each cell is allocated a number of carrier frequencies from the frequency band of the network to transmit information to mobile stations located within the cell, and in which carriers of a cell recur in another cell according to the determined frequency reuse factor, c h a r a c t e r i z e d in that

the carrier frequencies are divided into at least two frequency groups in each cell,

the carriers belonging to the same frequency group have the highest transmission power allowed to this frequency group,

each frequency group recurs in other cells of the network according to the frequency reuse factor characteristic of said frequency group.

2. A mobile telephone network according to claim 1, c h a r a c t e r i z e d in that

the highest allowable transmission power of a first frequency group is a maximum transmission power covering the entire cell area,

the highest allowable transmission power of all other frequency groups is a group-specific transmission power lower than said maximum transmission power, covering such a sub-cell of the cell area which corresponds to the frequency group.

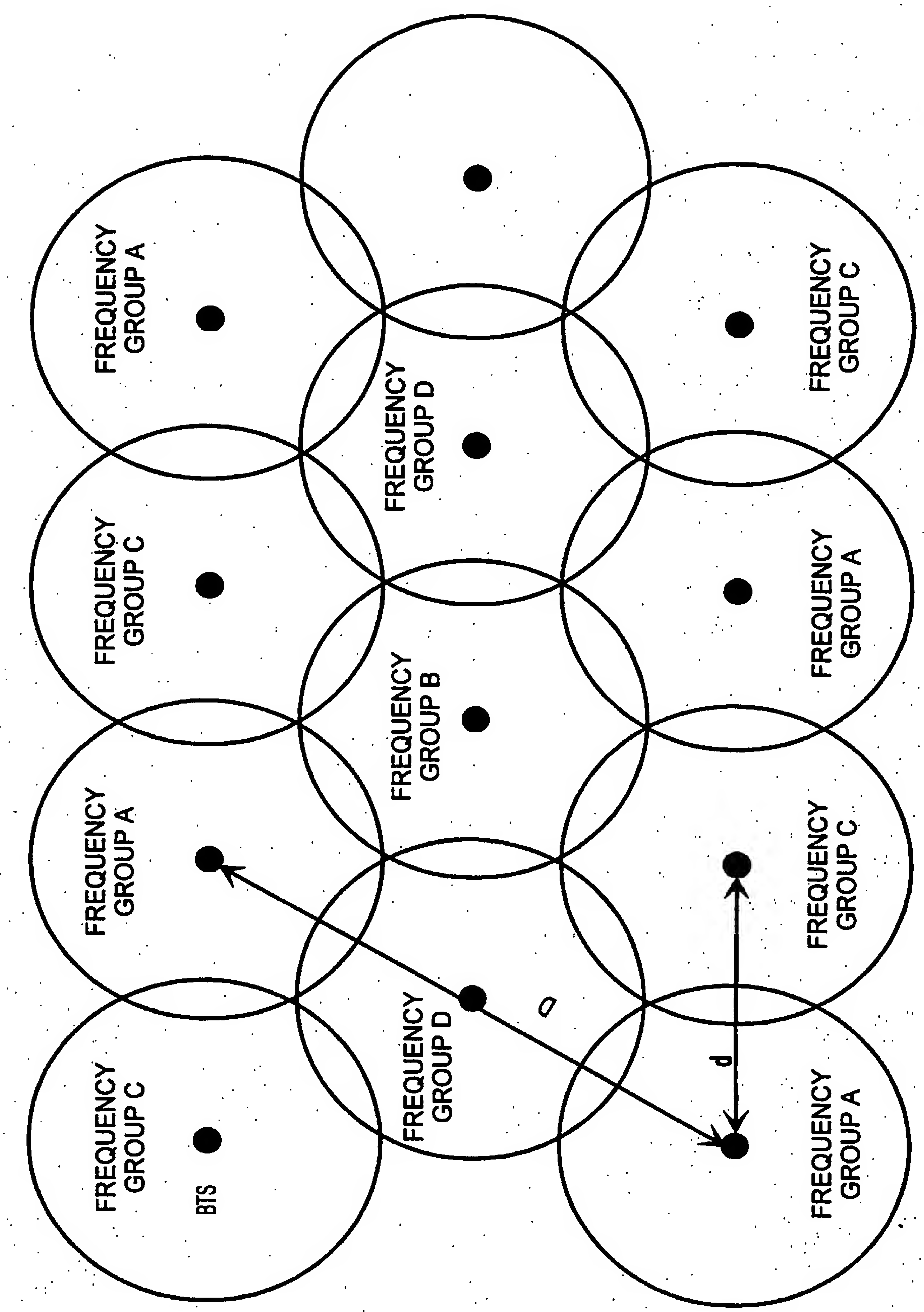
3. A mobile telephone network according to claim 2, c h a r a c t e r i z e d in that a base station broadcasts information intended for all mobile stations on a carrier which belongs to the first frequency group.

4. A mobile telephone network according to claim 2, c h a r a c t e r i z e d in that when a mobile station is located in an area where sub-cells overlap, the radio connection between the mobile station and a base

station employs a carrier which belongs to a frequency group using lower transmission power.

5. A mobile telephone network according to claim 2 or 4, characterized in that when a mobile station moves from a larger sub-cell into a smaller sub-cell, a handover is performed from a frequency group corresponding to the larger sub-cell to a frequency group corresponding to the smaller sub-cell.

6. A mobile telephone network according to claim 2 or 4, characterized in that when a mobile station moves from a smaller sub-cell into a larger sub-cell, a handover is performed from a frequency group corresponding to the smaller sub-cell to a frequency group corresponding to the larger sub-cell.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FREQUENCY GROUP A
FREQUENCY GROUP C
BTS
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FREQUENCY GROUP B
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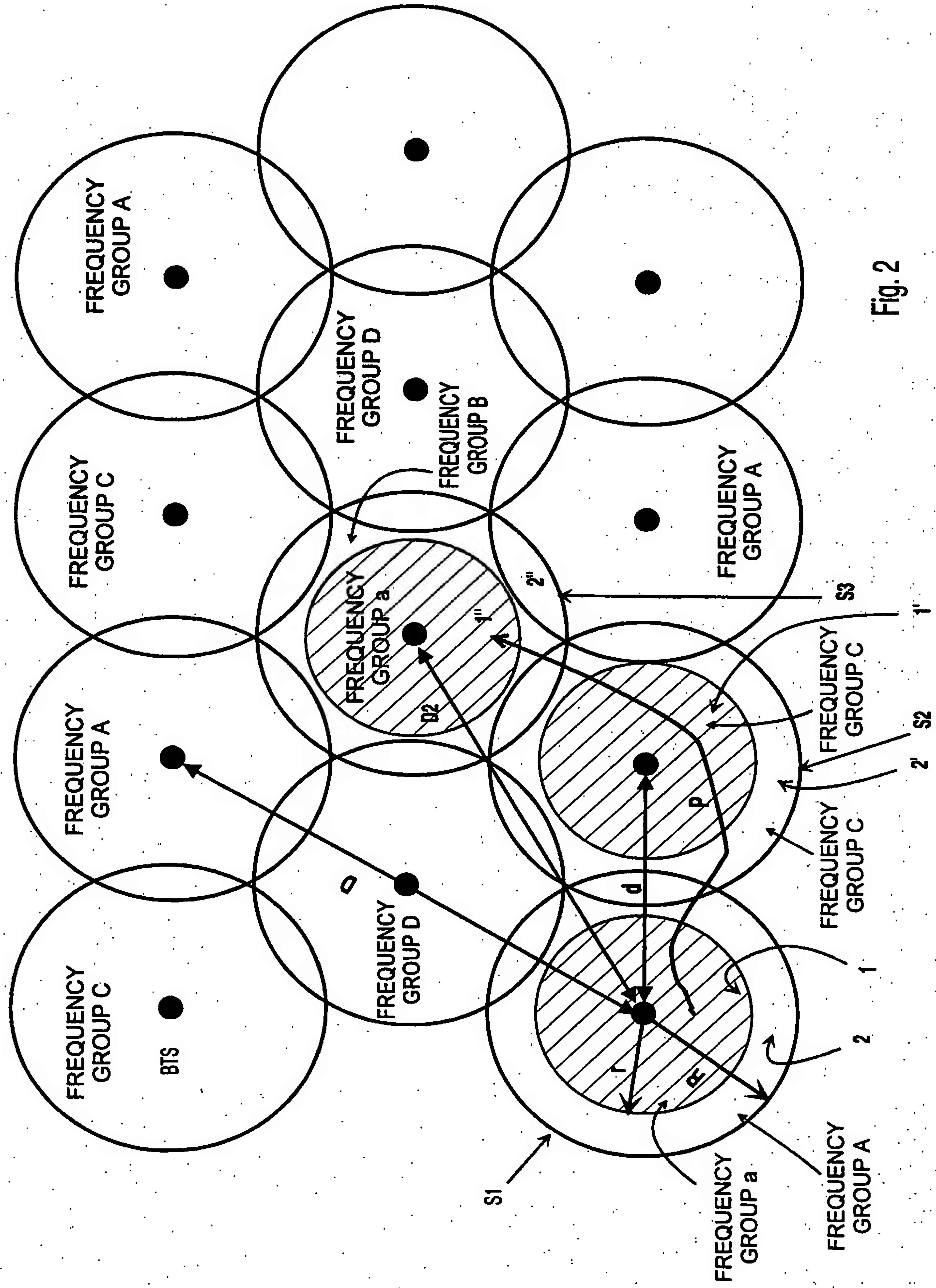
D
d
FREQUENCY GROUP C
FREQUENCY GROUP A
FREQUENCY GROUP C
FREQUENCY GROUP A

Fig. 1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FREQUENCY GROUP C
FREQUENCY GROUP C
FREQUENCY GROUP D
FREQUENCY GROUP C
BTS
FREQUENCY GROUP a
FREQUENCY GROUP A
D
D2
d
P
r
R
1
2
1'
2'
1"
2"
S1
S2
S3

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 96/00237

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04Q 7/36, H04Q 7/38
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 9508896 A1 (TELSTRA CORPORATION LIMITED), 30 March 1995 (30.03.95), page 3, line 1 - page 4, line 9; page 17, line 22 - page 18, line 7, abstract --	1-6
Y	EP 0531090 A2 (NIPPON TELEGRAPH AND TELEPHONE CORPORATION), 10 March 1993 (10.03.93), column 2, line 5 - line 53; column 5, line 12 - line 39, abstract --	1-6
A,P	EP 0667726 A2 (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.), 16 August 1995 (16.08.95), see whole document --	1-6

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	EP 0662776 A2 (ALCATEL SEL AKTIENGESELLSCHAFT), 12 July 1995 (12.07.95), see whole document -- --------	1-6

INTERNATIONAL SEARCH REPORT
Information on patent family members

05/09/96

International application No.
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WO-A1- 9508896	30/03/95	AU-A- 7733794	10/04/95
		FI-D- 961278	00/00/00
		NO-A- 961128	21/05/96
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EP-A2- 0667726	16/08/95	JP-A- 7274236	20/10/95
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		US-A- 5544171	06/08/96